Advanced Cosmic-ray Composition Experiment for the Space Station (ACCESS) Opportunities

This document specifies the Payload Support and Interface Module (PSIM) and the NASA-provided project services for the ACCESS mission. The ACCESS payload is comprised of two ultra high-energy particle detectors that operate synergistically on the International Space Station (ISS). The two instruments are a Transition Radiation Detector (TRD) and a Hadron Calorimeter (HC), which are stacked in a tandem configuration, as exemplified in Figure 1.2-1. The services and PSIM described herein cannot be provided for fundamentally different instruments or configurations, although different instrument designs and configurations can be accommodated as long as they meet the envelope and service constraints summarized in the sections below.

The content of this document is organized as follows:

- Section 1 specifies and illustrates the PSIM flight hardware and its functional capabilities.
- Section 2 specifies mission system verification and validation, which include mission level integration and testing. This section will also specify supports necessary for complying with the Shuttle and ISS requirements.
- Section 3 identifies and specifies Ground Support Equipment (GSE) that would be needed during mission level integration and testing at GSFC, including a shipping container for the ACCESS Payload to be transported from GSFC to KSC, only.
- Section 4 gives the GSFC costs for providing the above hardware and services.

1. Payload Support and Interface Module (PSIM)

The Payload Support and Interface Module (PSIM) is interface flight hardware designed to accommodate interfaces for the zenith-pointing full truss site on the International Space Station (ISS), while providing structural support for, power to, and data to and from science instruments. The PSIM is designed to support and interface with a Transition Radiation Detector (TRD) and a Hadron Calorimeter (HC). PSIM also meets the interface requirements of the Shuttle cargo-bay for launch and landing. Sections 1.1 to 1.7 describe the PSIM and its functional capabilities

1.1 PSIM Overview

The PSIM provides interfaces between the science instruments and the Payload Attach System (PAS) of the ISS external truss site. Additionally, it serves as a carrier during launch and landing in the Shuttle cargo-bay. The PSIM is designed to house science instruments as well as providing required interfaces, so that science measurements can be conducted on-orbit.

The PSIM consists of a mechanical structure, power system, thermal system, command and data handling system, a passive half of the PAS, extravehicular robotics (EVR) grapple fixtures, and extravehicular activity (EVA) handling fixtures. The PSIM design specifications include all of the applicable ISS external payload interface requirements, applicable STS requirements, and ACCESS mission requirements. The PSIM is basically a single string system. However, selective redundancy will be implemented for mission-critical or safety-critical areas as determined by risk and failure analyses.

1.2 Mechanical Structure

The PSIM mechanical structure is designed to support the ACCESS instruments and PSIM components throughout the payload's mission life of four (4) years on-orbit. The design requirements include launch and landing using the Shuttle. The requirements also include deployment on the ISS, on-orbit operations, and retrieval from the ISS. The baseline PSIM design is illustrated in Figure 1.2-1. The coordinate system of the access payload corresponds to that of the Space Shuttle Orbiter coordinate system unless otherwise denoted.

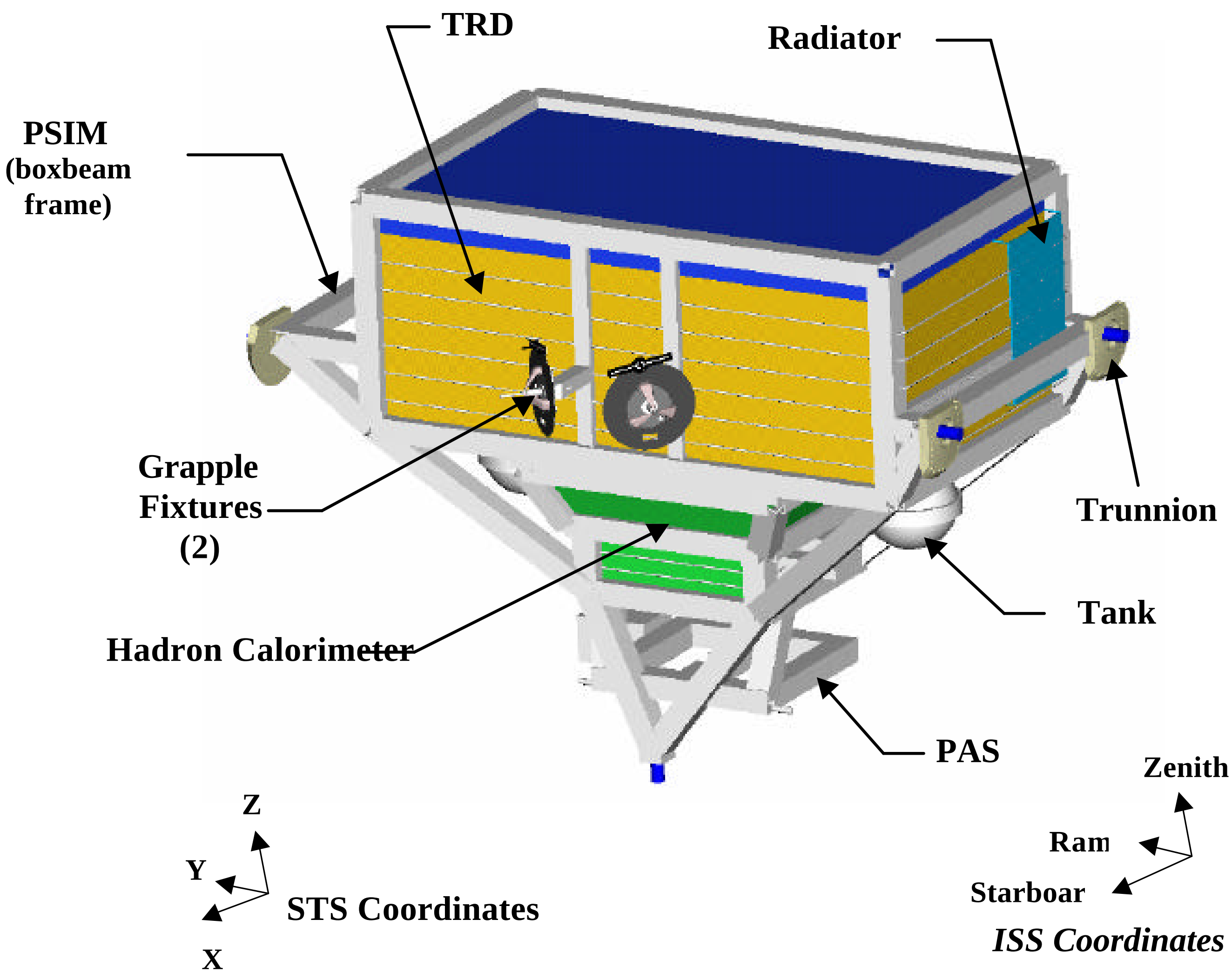

Figure 1.2-1: ACCESS Payload

Structure Description

The PSIM is a truss structure constructed of 7075 aluminum box beams. Dimensions of the main support beams are 15 cm x 15 cm x 1 cm, with a 1 cm wall thickness. The beam cross-section and the wall thickness vary in members where loading is not severe. In these members, an optimized combination of smaller cross-section beams and wall thickness are used to save weight, while still providing and maintaining acceptable structural stiffness and load-bearing capability**.**

Structural Interfaces to Instruments

The PSIM design accommodates the housing for two science instruments. The instruments attach to the PSIM beams along the edges of each instrument's structure, so that the PSIM provides a support frame around the specified instrument envelope. The PSIM beams then extend from the corners of each framed instrument to the trunnions. The trunnions are attach-points to the payload bay in the Shuttle.

The instrument design must include interfacing with the PSIM and must adapt to the PSIM configuration. The instrument interface structure will accommodate the routing of electrical cables and dedicated thermal links between the PSIM and the instrument

The instruments are arranged in tandem along the central axis of the detectors. The TRD is at the top of the stack, and the Hadron Calorimeter is at the base of the stack. When the payload is deployed on the ISS, the stack axis is aligned with the ISS zenith axis. This configuration is illustrated in Figure 1.2-1. When the payload is installed on the Shuttle, the stack axis is aligned with the Z-axis of the Shuttle, illustrated in Figure 1.2-1.

Component Configurations

Instrument electronics boxes mount to the outside of the instrument structure and inside the PSIM structure; thus, the boxes will be located between instrument and PSIM structures. Radiators, required for heat rejection by both the TRD and the Hadron Calorimeter, mount to both the ram and wake sides of each instrument for a total of four (4) radiators. Heat pipes run from the radiators around each instrument. The PSIM design can accommodate instrument gas management system. The tanks of the gas management system required for the TRD may mount to the PSIM on the wake and ram sides of the Hadron Calorimeter. A gas manifold snakes from each tank, outside the PSIM structure to the TRD.

The ACCESS payload attaches to the ISS using the PAS. The system enables a payload to mount mechanically and electrically to the attached payload sites on the ISS truss. The PAS consists of an active and passive half. The passive half is on the payload side, located below the calorimeter. It consists of three alignment bars and a capture bar for mechanically mating to the ISS, and a universal mating adapter for electrical mating to ISS power and data.

A total of five (5) trunnions secure the ACCESS payload to the Shuttle Cargo-Bay. Four (4) longeron trunnions attach to the sidewall beams in the Shuttle, and one keel trunnion mounts to the "floor" of the payload bay. Additionally, the ACCESS payload will be connected to the Shuttle Interface Panel (SIP) for survival power.

Two (2) grapple fixtures attach to beams on the +X side of the PSIM. These fixtures are used as attach points to the STS and ISS robotic arms. The grapples are oriented 90° from one another.

Fields-Of-View

The aperture of the ACCESS payload views space in the zenith direction from its position on the ISS. Since the instruments are in tandem with each other, both instruments point in this direction. Since the TRD has a rectangular aperture, its field-of-view is broader in one plane than the other. The Hadron Calorimeter has a square aperture and, hence, a symmetrical field-of-view in two orthogonal planes. The fields-of-view are unobstructed except for the U.S. and Russian solar panels, which rotate through the edges of the field-of-view as they are positioned for optimum solar energy impingement. Preliminary analyses predict that their passage through the ACCESS field-of-view will not be a problem, since the panels' low density does not significantly impede the high-energy particles being captured by the payload aperture.

Instrument Envelope

The PSIM provides an instrument envelope consisting of a rectangular box, representing the TRD envelope, joined a trapezoidal box, representing the Hadron Calorimeter envelope. The rectangular box has the dimensions of 3.35 m x 1.86 m x 1.28 m. The maximum length and width of the trapezoidal box at the "top", or the wider end of the trapezoidal shape is 1.49 m. The maximum length and width of the box along the opposite end is 1.00 m, the side adjacent to the ISS Payload Attach System (PAS). These dimensions are constrained by the allowable ISS attached payload envelope and they are non-negotiable. The height of the trapezoidal box is 1.0 m. The instrument envelopes are illustrated in Figure 1.2-2.

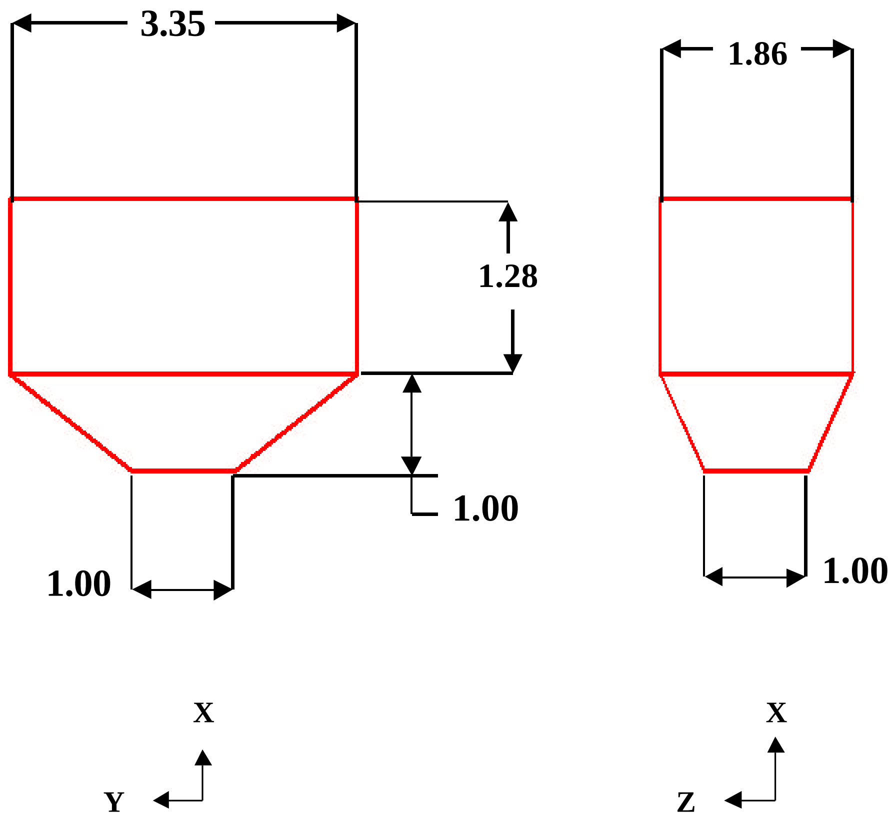

Figure 1.2-2: Instrument Envelopes (Dimensions in meters)

Instrument Mass and Center of Gravity

The PSIM can accommodate a combined instrument mass of 4530 kg (launch limit), the mass of which is exclusive of any instrument to the PSIM interface hardware and radiators. However, this mass is inclusive of any instrument hardware mounted on the spacecraft bus, such as tanks and electronics boxes. This mass must also meet the following center of gravity criteria. The X-axis center of gravity of both instruments combined will be no greater than 0.72 m. This distance is measured along the X-axis from the base of the instrument envelope towards the height. The Y-axis center of gravity of both instruments combined will be within 0.15 m of the X-axis. The Z-axis center of gravity of both instruments combined will also be within 0.15 m of the X-axis.

ISS and STS Interface Hardware

Extravehicular Robotic (EVR) grapple fixtures and the passive half of the ISS Payload Attach System (PAS) are considered part of the PSIM structure and they will be provided as part of this GFE.

1.3 Electrical Power

The power subsystem receives 120V DC (113V to 126V DC) from ISS, via PAS. The power system distributes and filters the 120V DC to the PSIM subsystems and instruments. The users will receive the 120V DC from the power subsystem and make the necessary conversion to the required low voltages and high voltages. Off-the-shelf power converters will be used for conversion to the low voltages. ISS also has a "Keep Alive Mode" where the power allocation to the external payload is limited to 500W. In this mode, power will only be available to the PSIM electronics, thermal system, and the gas system for the TRD. The PSIM power system can accommodate combined instrument operating power of 650W, orbit average. This power includes instrument heater power that may be needed during on-orbit cold case.

The current design for the power subsystem has two main modules: 1. the power module 2. the power distribution unit (PDU). The power module provides normal mode and common mode filters, in-rush current limit, and voltage and current monitors. The PDU provides both switched and un-switched individual power lines to all the users. The PDU provides switched power lines to the PSIM electronics, gas system, and instruments and un-switched power to the thermal system. The switched power lines will have a solid-state power controller as its switch. All the individual power lines will have over-voltage protection, under-voltage protection, and both voltage and current monitors. The un-switched power will have a fuse in-line for protection. Figure 1.3-1 illustrates the ACCESS PSIM power distribution system.

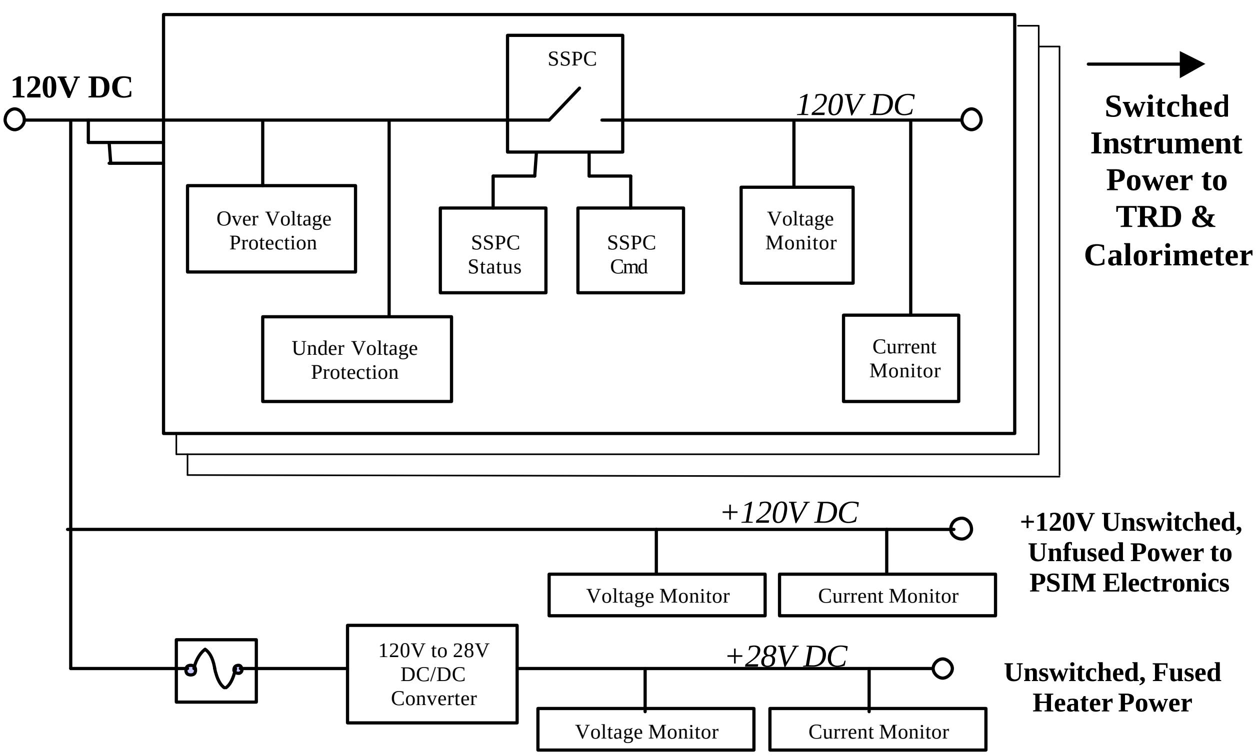

Figure 1.3-1: ACCESS PSIM Power Distribution System

1.4 Thermal System

The thermal design of ACCESS is semi-passive. Heat pipes, used to enhance heat transfer, eliminate hot spots, and help isothermalize the instruments. Heat pipes provide an optimum heat transfer path to the radiators and minimize their size by lowering the operating temperature. Heaters are provided for temperature-sensitive components, such as the TRD pressure container, and are used to maintain minimum temperature levels in a cold environment during a keep-alive mode. The design is straightforward and, by virtue of the very large time-constant, will provide reliable temperature control with small temperature differences and changes. The thermal design is based on keep-alive power of 500 W. The thermal portion of this GFE includes only radiators. All other thermal hardware needed for instrument, such as heat pipes and heater, are the responsibility of instrument developers.

Conceptual Design

A simplified schematic of the ACCESS thermal design is illustrated in Figure 1.4-1. Heat pipes are used to isothermalize and couple the instruments to the radiators on the wake-facing side of the module, where temperatures are maintained between 0 and 20°C. The attendant stand-alone electronic components are thermally coupled to passive radiators on the ram-facing side, where temperatures are maintained between 0 and 40°C. A multi-layered insulation (MLI) barrier is placed between these two regions to curtail heat transfer when the stand-alone electronics are above 20°C. Both radiators are covered with silver Teflon; all exterior surfaces of the instruments, other than the space radiators, will be covered with MLI.

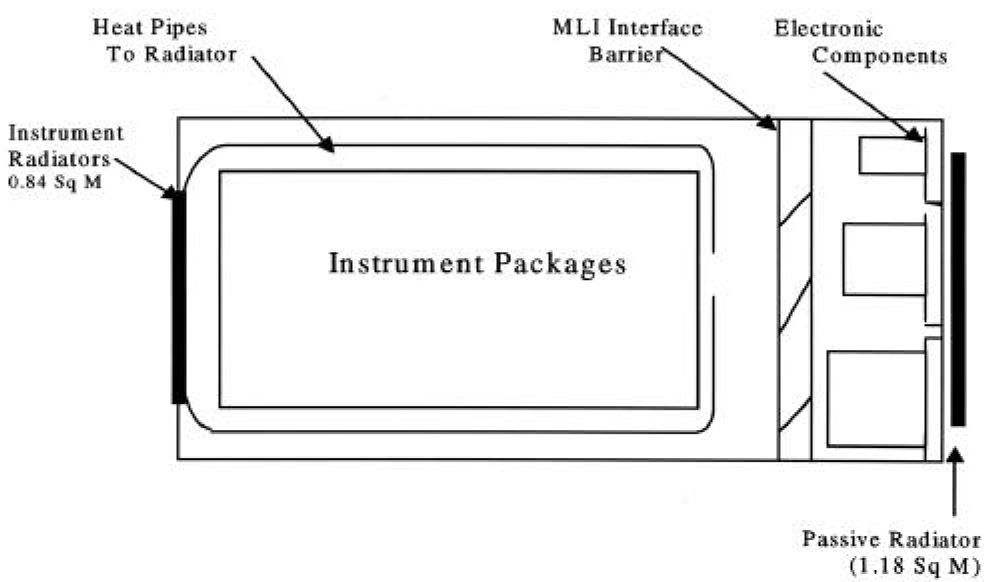

Figure 1.4-1: ACCESS Thermal System

Heat pipes are mounted in parallel rows and interface with the instruments at locations near the dissipating components, such as the photomultiplier tubes and heat-dissipating detectors and sensors. The aluminum structures afforded by the instruments provide efficient heat transfer paths to the heat pipe evaporators, so that circumferential gradients are minimized. This design also provides efficient heat transfer to space by allowing the radiators to operate at high temperatures about 5° C below the average instrument temperature.

The pipes, axially grooved and about 1.25 cm in diameter, use ammonia as the working substance. It is estimated that 30 heat pipes will be required to service the instruments and radiators. The heat pipes, conventional and constant conductance, will be embedded in the honeycomb radiator panel on 15 cm centers. (Parallelism between the rows must be maintained to facilitate pre-flight thermal balance testing.)

Heaters are the thin-wire resistance type, Kapton-insulated, Minco Thermofoil or equivalent. Thermostatic control will be provided for all heaters. Multi-layer insulation will be attached to the outside surfaces of the instruments and PSIM. The blankets consist of 20 sheets of aluminized Kapton with skim-cloth separators.

Radiator areas depend upon orientation, heat generation and the component temperature limits. By isolating the instruments with their relatively narrow temperature range (0 to 20°C) from the associated electronics with their wider temperature range (0 to 40°C), radiator areas and the related cold-case heater power will be minimized. Area calculations were determined from a mathematical model using the SINDA85/FLUINT program.

Transient Response

The thermal design is greatly simplified by virtue of the large thermal time constant afforded by the 4530 kg mass and an MLI enclosure. Transient response may be defined as a change in temperature, either heating or cooling, caused by a variation in internal heat dissipation or in the external heating environment. The very large thermal time constant inherent in ACCESS may be demonstrated by considering a hypothetical cool down in a cold-case environment, when internal power is suddenly reduced to zero. Even with all passive radiators, instrument temperatures are above –10°C at the end of 50 hours. Thus, since the ACCESS payload is very massive and has a large thermal time constant, its internal electronics will remain within a safe temperature range during a temporary power outage.

1.5 Command and Data Handling

The PSIM electronics serve as a bridge between the science instruments and the ISS power/data interfaces, and manage the operation of the entire payload. It is a single integrated unit that distributes commands, collects telemetry, records/stores science and engineering data, performs thermal and gas management housekeeping functions, and switches/distributes instrument power. A block diagram of the system and its interfaces is illustrated in Figure 1.5-1.

Instrument interfaces consist of only MIL-STD-1553 bus and power, with data exchanged using CCSDS (Consultative Committee for Space Data Systems) packet level protocols. The data system is able to store up to 52 Gbits of data between dumps. Conditioned, switched, and fused 120V power is fed to the instruments, with a total capacity of 710W available.

The PSIM electronics support the following modes of operation:

- Shuttle cargo bay: power available, limited functional tests, health/safety monitor
- Shuttle arm: powered OFF
- ISS arm: powered OFF
- ISS site (nominal): full power available, functional tests, normal operations
- ISS site (low power, 500 W): keep-alive power only, health/safety monitors only

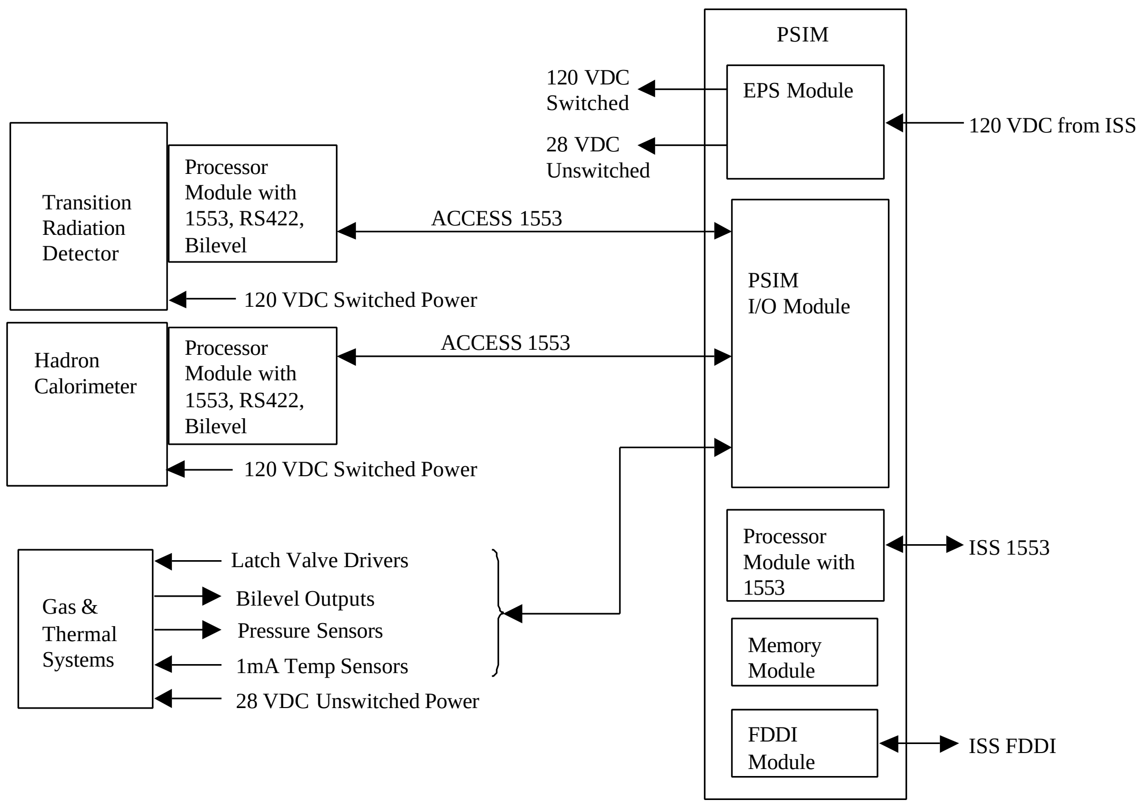

Figure 1.5-1: ACCESS PSIM Command and Data Handling System

The PSIM electronics support the following interfaces and functions:

- ISS 1553 bus (1 Mbps bandwidth): commands and housekeeping data
- ISS fiber bus (100 Mbps bandwidth): science data
- ISS 120V power: conditioned/ switched/fused service to each instrument

- PSIM 1553 bus (1 Mbps bandwidth): commands, instrument housekeeping, science data
- Data recorder: 52 Gbits capacity
- Provides thermal control/monitors (120V DC heater service)
- Provides gas system control/ monitors
- Electronics: 35 W average, local voltage converter
- Power distribution: 15 W average
- Thermal subsystem: 75 W (50 W instruments + 25 W gas system, infrequent)
- Gas subsystem: 100 W peak (200 ms pulse, infrequent)

1.6 STS and ISS Interfaces

The PSIM ISS/STS interface design complies with Shuttle and ISS interface Requirements--including, but not limited to SSP 42131, *Space Station Program Integrated Truss Segments P3 and S3 to Attached Payloads and Unpressurized Cargo Carriers (UCC), Standard Interface Control Document*, *and SSP 57003, the Attached Payload Interface Requirements Document. SSP 42004 Mobile Servicing System (MSS) to User Interface Control Document and NSTS-21000-IDD-ISS International Space Station Interface Definition Document.*

Extravehicular Robotics (EVR)

The baseline exchange scenario to transfer ACCESS from/to the Shuttle and ISS is by the use of robotics, namely, the Shuttle Remote Manipulator System (SRMS) and the Space Station Remote Manipulator System (SSRMS). The scenario requires the use of two grapple fixtures on the payload. The fixtures serve as the interface between the ACCESS payload and the robotic arms.

The location of the grapple fixtures on the payload is in part determined by the geometry and structural constraints of the payload itself, by the payload's position in the Shuttle payload bay and on ISS, and by the reach of the manipulator. ACCESS robotic interfaces will comply with Shuttle and ISS requirements including, but not limited to, *Space Station Program Robotic Systems Integration Standards (SSP 30550).*

To assist the crewmembers in grappling and docking ACCESS, a visual system of cameras and targets will be used as necessary. In addition, all transport activities can be monitored by an array of cameras on the Shuttle and ISS.

Extravehicular Activity (EVA)

ACCESS mission operations will not implement scheduled or unscheduled EVA, or intra-vehicular activity (IVA). ISS program, however, may require EVA for contingency cases only. ACCESS payload design and deployment configuration will maintain the appropriate EVA corridors necessary for contingency EVA accessibility. Appropriate EVA keep out or no touch/damage areas will be clearly identified in the event an EVA crew member comes in contact with ACCESS to preclude damage to sensitive instrument surface or components. ACCESS PSIM will also be equipped with an EVA releasable capture bar to assist in contingency manipulation of the payload in case of PAS malfunction.

1.7 Mission Operations

The transportation and installation of ACCESS Payload onto the space station site, the checkout of the PSIM, and removal of ACCESS and return after the mission is completed will be provided as NASA provided project services. The instrument will be either off or in a survival mode for these operations, except for brief functional checks before removal from the shuttle and after installation on the attach point. The instrument team is required to support these operations to provide advice on any instrument-related issues.

After PSIM checkout, the mission operation of ACCESS is the responsibility of the science team. Payload operations are accomplished through the Payload Operations Integration Center (POIC) at Marshall Space Flight Center (MSFC). Options for interfacing with the POIC are defined in SSP 50304, the POIC Capabilities Document. These options include remote operations using the Telescience Resources Kit (TReK). NASA will train the science team in the operations of the PSIM and provide sustaining engineering support in the event of operations anomalies associated with the PSIM.

2. Mission System Verification and Validation

Mission system verification and validation constitute NASA provided project services. These include requirements tracking, performance requirements verification, and functional requirements verification for system validation. The verification activities include mission system integration and test, system level analyses, inspection, and other acceptable verification methods. Also included are space Shuttle and ISS support services. All of the engineering tasks and management interfaces that are required for launching on Shuttle and deploying on the ISS will be provided. The following sections outline major tasks mentioned above.

2.1 Requirements Tracking and Verification

Mission requirements will be tracked to verify and validate system design. Requirements tracking system will be established to the lowest level possible and practicable. Verification methods for requirements will be established and overall system level consistency in verification methodologies will be determined. The ACCESS mission will implement verification methodologies that are consistent with the Goddard Environmental Verification Specifications (GEVS).

The acceptable verification methods are:

- Tests
- Analyses

- Demonstration
- Inspection

The above verification methods will be employed to verify mission requirements. Majority of the requirements will be subject to verification during mission integration and tests. The mission integration and test activities are specified below.

2.2 Mission Integration and Test (I&T)

The ACCESS mission integration and test will utilize GSFC integration and test facilities including environmental chambers. The mission integration and test will use the GSFC ISO 9001 certified Quality Management System. The GSFC Office of System Safety and Mission Assurance will support this activity. The mission integration and test activity includes environmental testing during which time the flight hardware will be subject to harsh environment that are expected in space environment. The successful environmental tests ensure end-to-end performance of the system. The environmental test program encompasses the STS/ISS requirements, stage requirements, and the predicted environmental conditions.

The ACCESS mission level environmental tests are as follows:

- EMI/EMC
  - Radiated and conducted emissions
  - Radiated and conducted susceptibility
  - Conducted emissions
  - Conducted susceptibility
- Mass properties
  - By Analysis
- Structural Loads
  - Coupled loads analysis
- Thermal Vacuum/Thermal Balance
  - 4 cycles at the system level
  - Maximum predict ±10 degrees
  - Hot and cold thermal balance performance test
- Acoustic
  - Workmanship at 138 dB level
- Shock
  - Tested at subsystem level
- Random Vibration
  - Tested at subsystem

The comprehensive performance test (CPT) will be executed to establish system performance baseline throughout all phases during I&T. CPT will be executed during environmental testing and system level trending will be established to predict overall system performance. System compatibility tests and mission simulations will be conducted to verify the ground to flight interfaces and ensure all systems are compatible and operating properly.

2.3 Space Shuttle and ISS Support Services

The GSFC will be the single point of contact in negotiating engineering services and operational support with the Space Shuttle and ISS Program Offices. These services will be properly documented in the Payload Integration Plans (PIP), their annexes and unique payload Interface Control Documents (ICD). Specifically the following:

Establish operational service requirements.

- Deployment/Retrieval, communications, data processing, photography, power, etc.

Establish controlling schedules for all major integration activities and data deliveries.

- Management and Technical Reviews (e.g. CIR, FOR, FRR, PSRP)
- Documentation (PIP, ICD and Annexes)
- Engineering analyses: Structures, Thermal, EMC/EMI
- Payload Safety Compliance Data

Establish guidelines and constraints for integration and planning.

Define integration tasks to be accomplished.

- The where/how/who/when payload is to be tested and placed into the orbiter and onto the ISS site
- Required purge and cleanliness levels

Establish interface verification requirements.

- CITE, ISS simulator, NBL testing and OPF testing

Establish the basis for Space Shuttle Program definition and pricing of optional services.

- Post-landing processing

Provide necessary data to enable mission performance planning, such as payload bay drawings and 3-D CAD models.

Establish compatibility of the orbiter, ISS and payload for flight.

3. Ground Support Equipment (GSE)

GSFC will provide the appropriate GSE for mechanical, electrical and data systems for system level test, verification and integration activities. GSFC will arrange for the ISS and Shuttle unique GSE or simulators needed to verify interfaces with the ISS and Shuttle. Some of the ACCESS GSE is listed below.

- Payload Lifting Sling
- Handling Fixtures
- Transporter/Shipping Container
- Data and Monitoring Equipment for Performance Testing
- ISS/STS Simulators

The instruments must provide their unique GSE in support of subsystem level testing, integration, diagnostics and transportation. Additionally, any GSE protective covers or monitoring equipment must be readily identified for removal before flight.

GSE, provided by GSFC, will conform to NASA design and safety standards such as KHB 1700.7. “Space Shuttle Payload Ground Safety Handbook”.

4. Cost

(To Be Supplied)